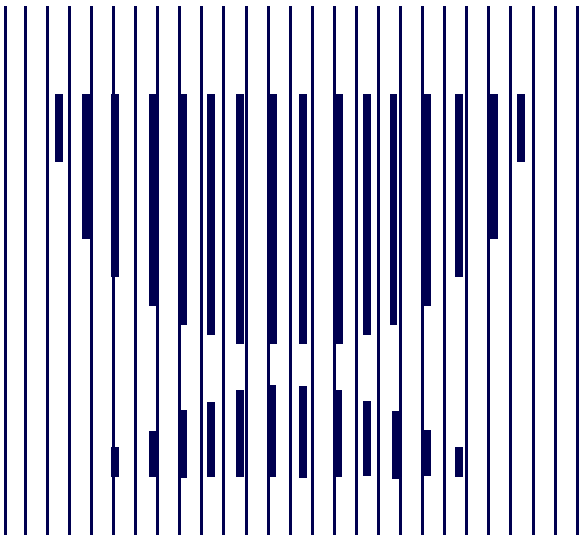
CBO MEMORANDUM

OPTIONS FOR STRATEGIC AIRLIFT

October 1995



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CONGRESSIONAL BUDGET OFFICE
SECOND AND D STREETS, S.W.
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This Congressional Budget Office (CBO) memorandum was prepared in response to a request from the Ranking Democratic Member of the House Committee on National Security. It reviews how requirements for strategic airlift have changed since the Cold War and looks at the costs and capabilities of three illustrative airlift purchases.

Rachel Schmidt of CBO's National Security Division and Victoria Fraider and JoAnn Vines of CBO's Budget Analysis Division prepared the memorandum under the direction of Cindy Williams, R. William Thomas, and Michael A. Miller. The authors gratefully acknowledge the careful assistance of Shaun Black and the useful comments of Lane Pierrot. Christian Spoor edited the manuscript, and Leah Mazade provided editorial assistance. Cynthia Cleveland prepared the memorandum for publication.

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SUMMARY

The need for strategic airlift, the planes that carry troops and equipment between continents, has lessened markedly in recent years. Current requirements for the first two weeks of a major regional conflict are 36 percent to 58 percent lower than those estimated during the Cold War for a confrontation with the Soviet Union. However, during the 1980s, the actual number of airlift aircraft was insufficient to handle the deliveries that the Department of Defense (DoD) estimated would be needed for a NATO/Warsaw Pact conflict. Current plans to maintain an airlift fleet with a theoretical capacity of 49 million to 52 million ton-miles per day come much closer to meeting delivery requirements that the Pentagon has set for itself. Yet critics might question why meeting DoD's airlift requirements is receiving relatively more emphasis today.

The defense bill for fiscal year 1996 will complete funding for 40 C-17 aircraft. Some military analysts would prefer to buy 80 to 100 additional C-17s to replace the Air Force's aging C-141 Starlifters. But a combination of C-17s and the Lockheed Martin C-5D or the C-33, a military version of Boeing's 747-400 freighter, might provide sufficient capability at lower cost.

The Congress might want to consider three criteria for evaluating airlift options: ability to meet delivery requirements for two major regional conflicts; ability to perform special missions, such as air-dropping a brigade after traveling between continents or repositioning outsize equipment within a theater by air; and cost. How to balance the tradeoffs between performance and cost depends on the likelihood that the United States will become involved in two major conflicts at the same time or in crises that will require U.S. forces to perform special missions.

After the Air Force retires its C-141s, purchasing 80 more C-17s would allow it to meet its airlift requirements, increase the share of planes in its fleet that can carry outsize cargo, and address special military missions. Based on the Congressional Budget Office's (CBO's) estimates, the Air Force would pay more than $36 billion (in 1996 dollars) to purchase and operate 80 additional C-17s through 2020.

DoD is planning to send less outsize cargo to major regional contingencies than it would have sent to a NATO/Warsaw Pact conflict. Thus, a mixture of C-17s and planes that cannot carry most outsize equipment, such as C-33s, might still meet requirements to deliver cargo to major regional contingencies. If there was adequate room at airfields in regions of potential conflict, buying 32 more C-17s plus 30 C-33s would provide the same delivery capability as 80 additional C-17s. That option would also be nearly $8 billion cheaper: it would cost about $28 billion to buy and operate the planes through 2020 (in 1996 dollars). If, however, U.S. forces were limited to a few airfields that had a small amount of ramp space, that option might

not deliver cargo as quickly as would 80 more C-17s. And such a combination would not provide as much flexibility to handle specific military missions such as strategic brigade airdrops.

Compared with the C-33, the C-5D might enhance DoD's ability to perform some military missions but still cost less than buying only C-17s. CBO estimates that buying and operating 65 C-5Ds would cost more than $27 billion through 2020—nearly $9 billion less than 80 additional C-17s (in 1996 dollars). However, the C-5D does not have all of the C-17's capabilities. For example, it could not be used to land on the shortest runways. And if access to airfields was limited, a fleet with 65 C-5Ds might not deliver cargo as quickly as could 80 additional C-17s.

The appropriate mixture of planes depends on how much DoD and the Congress are willing to pay for the flexibility provided by 80 additional C-17s. The options described in this memorandum could cost $8 billion to $9 billion less through 2020. The near-term costs of those alternatives could be higher or lower than for 80 more C-17s, depending on the timing of the purchases. Those cost issues may be of particular concern now, when the Congress is adding acquisition programs to the defense budget and, at the same time, trying to eliminate the federal budget deficit.

INTRODUCTION

Most types of U.S. military forces have been cut over the past several years. But one mission that the Department of Defense (DoD) has made a priority for new investment spending is strategic airlift—aircraft that carry troops and equipment over intercontinental distances. In DoD's Future Years Defense Program for 1996 to 2001, $21.1 billion would go toward acquiring new aircraft to replace the aging C-141 Starlifter. The Administration has not yet recommended which aircraft to buy, but three under consideration are the McDonnell Douglas C-17, Lockheed Martin's C-5D, and the C-33, a new military version of Boeing's 747-400 freighter. Ultimately, whatever plane or mixture of planes the Congress decides to buy will account for one of the largest defense procurement programs through the remainder of the decade.

In December 1993, DoD officials put the C-17 program on probation for two years because of its significant cost growth and difficulty achieving performance goals.[1] The two-year period has given the Air Force and McDonnell Douglas a chance to demonstrate whether the C-17 can operate at its planned wartime utilization rate of 15.2 hours per day. The aircraft exceeded that goal during a monthlong evaluation in July 1995. In addition, McDonnell Douglas has reduced its estimate of production costs and reportedly has proposed a fixed-price offer for further C-17s at prices lower than were previously thought achievable.

Yet even with that turnaround in the program, questions remain about the cost-effectiveness of the C-17. The C-5D and the C-33 are expected to cost less, and both of those planes can carry a much larger average payload than the C-17. Thus, the Air Force might be able to procure fewer aircraft and still meet its lift goals. However, the C-17 is the most flexible of the three planes. It can handle a wide variety of missions that are unique to the military, such as moving outsize cargo within a theater, air-dropping paratroopers or equipment, and landing on short or ill-equipped airfields. The questions now at hand for defense policymakers are these: How important will the C-17's unique capabilities be in future conflicts? What premium would DoD pay for those capabilities? And can a mixture of aircraft satisfy both general strategic lift needs and more specialized military missions?

Airlift in Perspective

The importance of strategic lift results from the assumptions and planning scenarios of U.S. national security strategy. Current plans require U.S. forces to prepare for a set of conflicts that occur nearly simultaneously—the most demanding scenario

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1. For a discussion of the cost and performance issues in the C-17 program, see Congressional Budget Office, "The C-17: Costs and Alternatives," CBO Paper (August 1993); and General Accounting Office, *C-17 Aircraft: Cost and Performance Issues*, GAO/NSIAD-95-26 (January 1995).

being a conflict on the Korean Peninsula followed by another in Southwest Asia (the Middle East). DoD uses the scenarios in its Mobility Requirements Study Bottom-Up Review Update (MRS BURU), released to the Congress in early 1995, to set its goals for strategic lift. The MRS BURU poses a set of assumptions and then uses simulations of warfighting and deployment schedules to estimate the number of airlift planes and ships needed to deliver U.S. forces to those regional contingencies.

In order to halt initial assaults threatening key assets such as ports and airfields, the United States now plans to deploy larger numbers of heavy forces much more quickly than in previous plans. Under mobilization plans for the end of this decade, the Army would deploy an entire heavy division in about two weeks. That is a more demanding requirement than earlier analyses had assumed or than was achieved in the Persian Gulf War. For example, in the 1992 Mobility Requirements Study (the last mobility analysis conducted before the Bottom-Up Review), only one brigade of heavy forces was to be delivered within the first two weeks of deployment. During Operation Desert Shield, the first heavy unit to arrive—the 24th Mechanized Infantry Division—was not fully in place until 47 days after the United States began deploying forces to the region.

DoD recently expanded the amount of equipment and supplies it has prepositioned near Southwest Asia and Korea. One set of equipment for a heavy brigade is now prepositioned on land in Kuwait, and Administration officials have entered negotiations to place one or two others elsewhere in Southwest Asia. Similarly, the Army is planning to supplement the 2nd Infantry Division in South Korea by prepositioning equipment for a heavy brigade. The Army has also placed equipment that can be tailored for an armored or mechanized brigade or an armored cavalry regiment on board roll-on/roll-off ships in the Indian Ocean. Those ships also contain 30 days' worth of supplies for contingency forces.

Because of those investments, DoD may be able to deliver heavy forces more quickly than it did during Operation Desert Shield. During the October 1994 deployment to Southwest Asia known as Vigilant Warrior, for example, the Army demonstrated the usefulness of its afloat prepositioning concept. Aircraft from the Air Force and planes volunteered by the Civil Reserve Air Fleet (CRAF) flew elements of the 24th Infantry Division to meet up with equipment stored both on land and on board prepositioned ships that steamed to the region. Because of that prepositioned equipment, the deployment of mechanized forces and support units in October 1994 took place at a considerably faster pace than during Desert Shield.

Setting Requirements for Strategic Airlift

The earliest forces sent to a conflict rely on a combination of airlift and prepositioned equipment to deploy in a theater, since even the fastest type of sealift ship takes roughly three weeks to reach the Persian Gulf. DoD bases its requirements for the size of the airlift fleet and prepositioned stocks on estimates of the amount of equipment and number of troops required to halt an enemy assault. Those estimates are derived from DoD's warfighting simulations and assumptions about the size of enemy forces and how such an assault might proceed. Although the precise timing of operations remains classified, defense officials expect that the halting phase of a conflict will last roughly two to three weeks.

Since prepositioning places equipment closer to a potential region of conflict, a deployment strategy that relies heavily on prepositioned forces should theoretically lead to lower requirements for airlift. However, military officials do not plan to preposition some types of equipment, such as helicopters and Patriot missiles, because they are too few in number or difficult to maintain aboard prepositioning ships. Thus, although prepositioning equipment decreases the need for DoD to lift some pieces of heavy cargo, airlift planes are still needed to deliver the remaining equipment, the troops who operate it, support for tactical air forces, and lighter military units.

Today's airlift needs are substantially lower than those during the Cold War (see Figure 1). In 1981, a DoD analysis known as the Congressionally Mandated Mobility Study (CMMS) estimated airlift needs for a war between NATO and the Warsaw Pact, along with other, less demanding scenarios in the Persian Gulf and Iran. Compared with its findings, early lift requirements for the Bottom-Up Review's Korean and Southwest Asian scenarios are between 36 percent and 58 percent lower than requirements for a major confrontation with the Soviet Union, as measured in millions of ton-miles. (Ton-miles measure the weight of equipment deploying to a region multiplied by the distance carried.)

Actual Delivery Capability Versus Theoretical Fleet Capacity

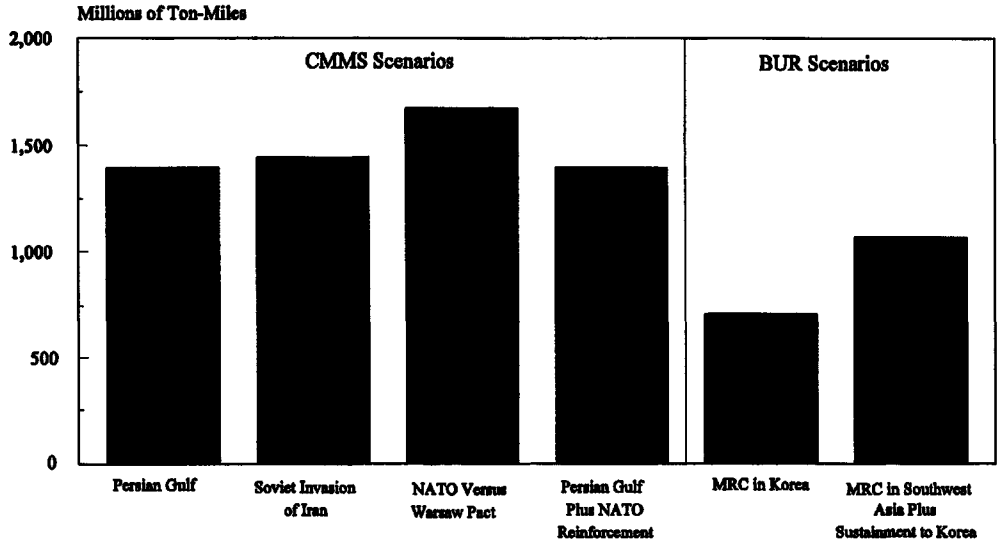
For budgeting and planning purposes, the Air Force describes the capability of its airlift fleet in terms of theoretical capacity, based on average measures of performance (such as payload and flight speed) for each plane in a fully mobilized fleet. However, a fleet's actual ability to deliver cargo to a theater tends to be far less than its theoretical capacity.

For example, at the time of Desert Shield, the theoretical capacity of U.S. airlifters and all Civil Reserve Air Fleet planes was 48 million ton-miles per day

(MTM/D). However, some aircraft were withheld for other missions or suffered from maintenance problems; commercial planes in Stage 3 of CRAF were never called into service; and reserve aircrews were only partially mobilized. As a result, actual deliveries averaged 17 MTM/D during the first six weeks of operations and peaked at 21 MTM/D during January 1991—or 35 percent and 44 percent of theoretical capacity, respectively.

One result of the 1981 CMMS was a recommendation that DoD try to obtain a fleet of military airlifters and CRAF planes with a theoretical capacity of 66 MTM/D. That goal was used to support the development of the C-17 (originally with a planned purchase of 210 planes) and led to the procurement of C-5B and KC-10 aircraft as a near-term solution to the shortfall. Yet even with significant investments

FIGURE 1. AIRLIFT REQUIREMENTS FOR THE FIRST TWO WEEKS OF DEPLOYMENT



SOURCES: Unclassified airlift requirements for the Cold War era taken from Department of Defense, Under Secretary of Defense for Research and Engineering, *Congressionally-Mandated Mobility Study (Secret)* (1981); requirements for a major regional contingency in Korea followed by one in Southwest Asia provided by the Department of Defense.

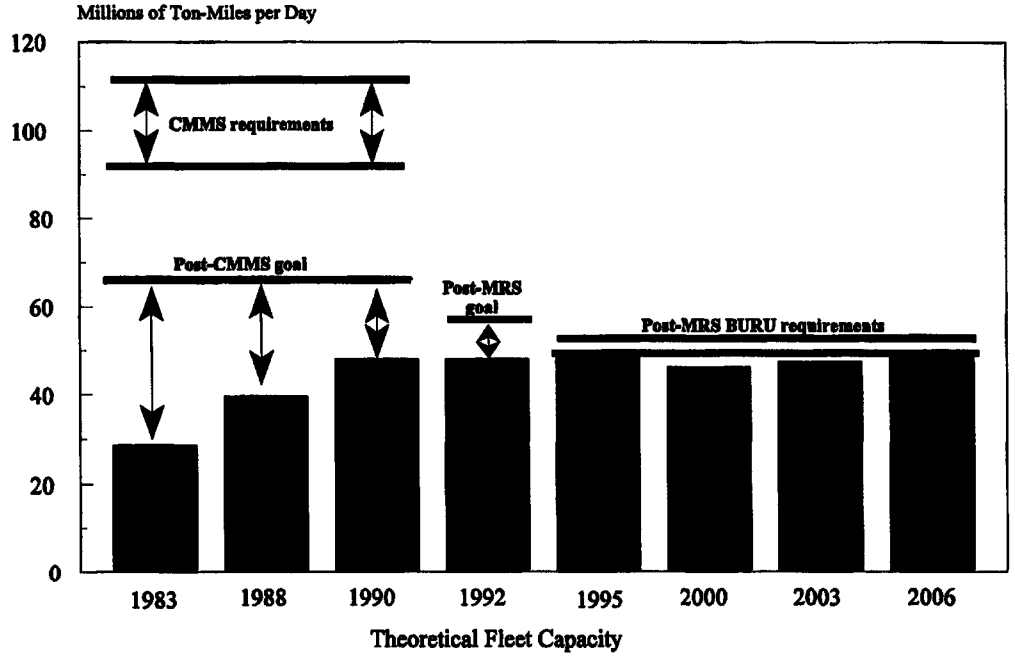
NOTES: Since the Bottom-Up Review scenarios occur nearly simultaneously but more than two weeks apart, the requirements for a conflict in Southwest Asia also include supplies that must be flown to the first conflict in Korea. Requirements for conflicts in Korea and Southwest Asia include force deterrent options (FDOs) that begin prior to the official start of deployment. Excluding weight associated with FDOs would mean that early airlift requirements for Korea and Southwest Asia were each about 65 percent lower than those for a NATO/Warsaw Pact conflict.

CMMS = Congressionally Mandated Mobility Study; BUR = Bottom-Up Review; MRC = major regional contingency.

in airlift capacity during the 1980s, DoD never reached that goal. At its peak, total airlift capacity was just below 50 MTM/D. And even if DoD had reached it, the 66 MTM/D goal was limited by fiscal realities: it was actually insufficient to handle the airlift requirements estimated in the CMMS (see Figure 2).

Because of factors such as those that applied during Desert Shield and other limits on the number of planes that can be serviced en route and in-theater, a fleet with a theoretical capacity of 66 MTM/D would have much smaller actual

FIGURE 2. AIRLIFT FLEET CAPABILITIES, GOALS, AND REQUIREMENTS



SOURCES: U.S. Air Force, *Airlift Master Plan* (1983); Secretary of Defense, *Annual Report to the President and the Congress* (various years).

NOTES: Projections of future fleet capabilities are based on continued purchases of C-17s or purchases of other aircraft with the equivalent amount of ton-miles per day. The projections use standard planning assumptions of the Air Mobility Command.

CMMS = Congressionally Mandated Mobility Study; MRS = Mobility Requirements Study; MRS BURU = Mobility Requirements Study Bottom-Up Review Update.

effectiveness.[2] In fact, DoD's estimates suggest that a 66 MTM/D fleet composed of 210 C-17s plus C-5s, C-141s, KC-10s, and a robust CRAF program would probably achieve an operational effectiveness over the first two weeks of deployment of about 40 MTM/D in a NATO/Warsaw Pact conflict, or 35 to 50 MTM/D in a Persian Gulf contingency.[3] Thus, even if DoD had been able to achieve the 66 MTM/D goal for theoretical capacity, such a fleet would have addressed only 35 percent to 50 percent of the requirements estimated in the CMMS. Put another way, the fleet might have taken twice as long or longer to airlift forces to Europe as commanders said was necessary to halt a Soviet offensive.

Mobility analyses that are based on current planning scenarios have set lower airlift requirements than those of the Cold War era. Based on the 1992 Mobility Requirements Study, which posited two "concurrent sequential" major regional conflicts, DoD established a target of 57 MTM/D for its airlift fleet capability. The 1995 Mobility Requirements Study Bottom-Up Review Update further lowered airlift requirements to 49 to 52 MTM/D, depending on the degree to which the United States was able to preposition stocks of gear and supplies abroad. That range essentially calls for keeping the airlift fleet's theoretical capacity at its current level. However, the Air Force plans to retire the C-141 by 2006 (studies by the Institute for Defense Analyses and DoD's Scientific Advisory Board suggested that a service-life-extension program for the C-141 might not be cost-effective or worthwhile technically).[4] In order to hold the capability of the current fleet level, the Air Force will need to procure replacement aircraft.

HOW MANY C-17s ARE NEEDED?

The Department of Defense is considering whether to propose buying only C-17s or a mixture of aircraft. Alternatives will be judged on three measures: how well each option's fleet can deliver the heavy cargo needed for the first two weeks of nearly simultaneous conflicts in Korea and Southwest Asia; how well it performs specialized military missions such as airdrop; and how much it is expected to cost.

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2. In military parlance, factors such as an airfield's ramp space, the availability of fuel and manpower to service aircraft, and the speed at which planes can be loaded or unloaded are called maximum on-the-ground, or MOG, constraints.

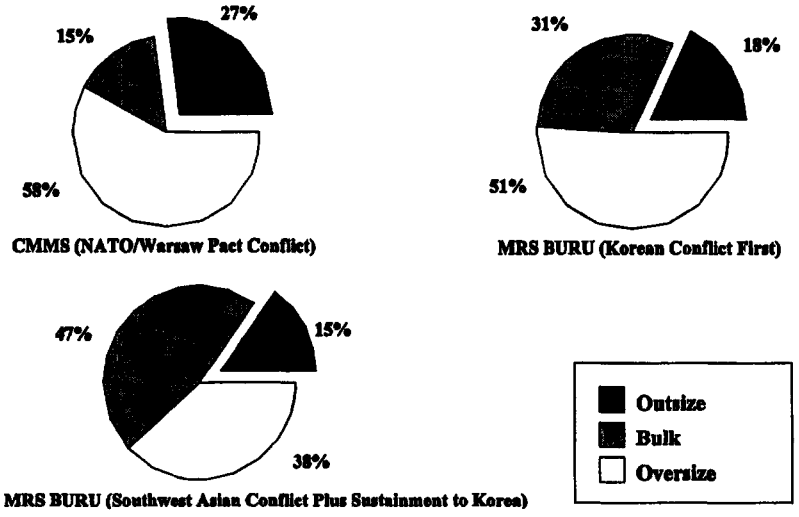
3. Department of Defense, *DoD Airlift Requirements: Report to Congress Required by the National Defense Authorization Act for Fiscal Year 1994* (January 1995).

4. W. L. Greer, *Cost and Operational Effectiveness Analysis of the C-17 Program,* Report R-390 (Alexandria, Va.: Institute for Defense Analyses, December 1993), p. ES-9; Jeff Cole, "Report Warns Against Plans to Refit C-141," *Wall Street Journal,* August 23, 1993, pp. A3, A12.

Heavy Cargo Deliveries

The mix of equipment DoD plans to airlift to a major regional contingency today differs from what it planned to send for a conflict with the Soviet Union. Military planners categorize airlift loads into three sizes: bulk loads that fit on a standard pallet, oversize loads that are larger than bulk loads but will fit into a C-141, and outsize loads that can fit only on a C-5 or C-17. According to the CMMS, 27 percent (by weight) of the equipment that DoD planned to send to a NATO/Warsaw Pact conflict within the first two weeks was outsize (see Figure 3). By comparison, DoD's simulations of deployments to Korea and Southwest Asia suggest that 15 percent to 18 percent of airlift deliveries over a similar period will be outsize. Official data for the first two weeks of Desert Shield are unavailable, but approximately 10 percent

FIGURE 3. SHARES OF EARLY AIRLIFT REQUIREMENTS BY CARGO TYPE



SOURCE: Congressional Budget Office based on data from the Department of Defense.

NOTES: The percentages above show the shares of cumulative airlift deliveries within the first two weeks of deployment. Since the Bottom-Up Review scenarios occur nearly simultaneously but more than two weeks apart, the requirements for a conflict in Southwest Asia also include supplies that must be flown to the first conflict in Korea.

CMMS = Congressionally Mandated Mobility Study; MRS BURU = Mobility Requirements Study Bottom-Up Review Update.

(by weight) of the cargo loads were outsize and half were bulk during the first month of deployment to the Persian Gulf.[5]

The decline in the requirement for carrying outsize cargo is an important issue in the debate over how many more C-17s are needed. One advantage of the C-17 and C-5 relative to the C-33 is their ability to carry such cargo. However, if a large proportion of the equipment that DoD plans to send can fit on the C-33, then a mixture of planes might be equally effective.

Advocates of the C-17 and C-5 point out that those planes were designed specifically with military loads in mind. Both aircraft have wings that are high on their fuselages and ramps that lower to the ground so that military equipment can move on and off quickly. The planes also have large doors and unobstructed cargo compartments capable of handling outsize equipment, as well as reinforced floors to handle heavy loads. The ramps and floors of the C-17 and C-5 were designed so that those planes can air-drop equipment while in flight. The C-17 also has a system of thrust-reversers, flaps, and slats that allows it to land on short airfields, much like the smaller C-130 can.

By comparison, the 747-400 freighter (on which the C-33 is based) was designed to maximize range while carrying a large payload of standard containerized cargo. Its cargo compartment is much higher off the ground than a military airlifter's. As a result, the Air Force would need to transport loaders and other material-handling equipment (as it does for its KC-10s) in order to move supplies on and off the C-33, and loading the aircraft might take more time. But the C-33 would most likely be constructed with wider doors and stronger floors than the civil version of the 747 to handle heavier and bulkier military equipment. And the C-33 would be capable of carrying an average payload more than 60 percent larger than that of the C-17 over a much longer range—potentially reducing the need to refuel airlift planes in flight.

Based on data from the Department of Defense, the Congressional Budget Office (CBO) estimates that at least 70 percent (by weight) of equipment that military officials plan to airlift to major contingencies in Korea and Southwest Asia could fit on the C-33—that is, all bulk cargo, most oversize equipment, and a few outsize pieces. The plane would not be able to accommodate equipment such as attack, scout, and utility helicopters, or some heavy trucks and vehicles that are built on tank chassis, but it would hold more types of cargo than most CRAF aircraft or the standard configuration of the 747-400 freighter.

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5. Jean Gebman, Lois Batchelder, and Katherine Poehlmann, *Finding the Right Mix of Military and Civil Aircraft, Issues and Implications*, vol. 2, *Analysis*, MR-406/2-AF (Santa Monica, Calif.: RAND, 1994).

However, exactly how many C-33s or C-5s would be needed to replace the delivery capability of a given number of C-17s is subject to debate. Although the C-17 carries a smaller payload, its size does have an important benefit: making airfields that have a limited amount of ramp space for parking and loading more accessible.

Air Force officials argue that since the C-17 is smaller, more maneuverable on the ground, and can be loaded or unloaded quickly, it holds an advantage when airfield conditions are constrained. DoD's major planning scenarios—Korea and Southwest Asia—include several large airfields.[6] But the maximum number of planes that can be serviced on an airfield can change at any given time, depending on such factors as the availability of ramp space, fuel, manpower, and equipment for loading and unloading aircraft. For that reason, it is difficult to say to what degree ramp space and other factors could constrain deliveries to two major regional conflicts.

Using planned deployments for two "concurrent sequential" conflicts in Southwest Asia and Korea, a 1993 study by the Institute for Defense Analyses showed that a fleet of 120 C-17s could deliver more outsize cargo than fleets that included a mixture of C-17s and modified commercial wide-body planes when airfields were constrained as tightly as they were early in Operation Desert Shield. However, when airfield space was less cramped, alternative fleets could meet airlift requirements for the first 30 days of a major conflict at lower cost.[7]

To provide more up-to-date information about how well a mixture of planes can deliver cargo, the Air Force has been conducting a study called the Strategic Airlift Force Mix Analysis (SAFMA). The study focuses on airlift requirements in the halting phase of the most demanding scenario for airlift within the MRS BURU: a major conflict in Korea followed by another in Southwest Asia. The Air Force expects to release the results of the study to the Congress after November 1995, when the Pentagon's Defense Acquisition Board will set DoD's course for future purchases of strategic airlift planes.

In the SAFMA study, the Air Force uses a model that simulates the deliveries of individual planes to estimate the number of C-33s that would be necessary to complement various purchases of C-17s: for instance, if the Air Force stopped C-17 procurement at 40, 58, 72, 86, or 100 planes. For each of those quantities, the model calculates how many C-33s are needed to precisely match the delivery of outsize, oversize, and bulk cargo provided by a fleet with 120 C-17s. Using that approach,

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6. General Accounting Office, *C-17 Aircraft*, p. 36.

7. Greer, *Cost and Operational Effectiveness Analysis of the C-17 Program.*

a fleet with fewer planes that can carry outsize cargo (that is, with more C-33s) might come quite close to delivering as much cargo as 80 additional C-17s, yet never exactly match their output—and therefore might not be considered a viable alternative. Nonetheless, prepositioning such outsize equipment near a region of potential conflict while purchasing a mixture of strategic airlifters might be more cost-effective.

Missions Unique to the Military

A fleet with a larger number of C-17s may be better able to conduct specialized missions. The Army, for example, has a military requirement to be able to perform airdrop operations with brigade-size forces, possibly over intercontinental distances. And some military officials envision using the C-17 to transfer outsize cargo within a war theater or to deliver cargo directly from the United States near the frontline of a conflict.

Aside from requirements to airlift cargo to major regional conflicts, the appropriate mix of planes in the Air Force's fleet depends on how often DoD needs to perform those specialized missions, and how much defense leaders and the Congress are willing to pay for that capability. The Secretary of Defense's Director for Program Analysis and Evaluation has been conducting a Tactical Utility Analysis to provide information about how much flexibility more C-17s would provide compared with various mixtures of planes. That study analyzes how well various fleets would perform strategic brigade airdrops, deliver cargo to lesser regional contingencies, provide strategic deliveries directly to forward airfields, or reposition equipment within a theater. Although its results have not yet been released to the Congress, press reports suggest that conducting brigade-size airdrops could require larger numbers of C-17s—as could using C-17s for intratheater deliveries, since those planes used as tactical airlifters might not be available for a strategic deployment.[8]

Strategic Brigade Airdrop. One mission that separates the C-17 from its competitors is strategic brigade airdrop—planned as a forced-entry operation in which airborne troops and equipment are dropped after traveling long distances. Such a mission would be followed by equipment delivered by aircraft that land at nearby airfields.

Current plans are to use the C-17 for the airdrop mission as C-141 Starlifters are retired from service. Initially, paratroopers had difficulty jumping from the C-17.

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8. David A. Fulghum, "Defense Studies Back Large C-17, C-33 Buys," *Aviation Week & Space Technology*, September 18, 1995, p. 26; and "Joint Chiefs to Push C-17, C-33 Mix," *Aviation Week & Space Technology*, October 2, 1995, pp. 63-64.

For example, some paratroopers came into contact with their deployment bags during mass jumps, and Army and Air Force officials feared that parachute lines would become entangled when jumpers exited from opposite sides of the aircraft. In order to fix those problems, the Air Force and the Army have changed operational procedures to avoid parachute entanglements. For example, the Army has lengthened the static line to which deployment bags are attached, raised the C-17's angle of attack during paratrooper deployment, and limited the aircraft's weight during jumps. Although those changes ensure that paratroopers can jump safely, if the C-17's weight is reduced by carrying less fuel, its range when conducting airdrop operations may be limited.

In case DoD should purchase fewer than 120 C-17s, the Air Force has also conducted three sets of airdrop tests on its C-5s. During those evaluations, the parachutes of test dummies were hit by the plane's wake. The Army would like to see further evaluation of the C-5 before plans are made to use it for air-dropping either heavy equipment or personnel. Although the Air Force is not pursuing plans to drop paratroopers from the C-5, officials do believe it can be used to air-drop heavy equipment and containerized delivery system bundles.

The Army has air-dropped paratroopers in actual missions only rarely —airborne forces were dropped in 1983 during Operation Urgent Fury in Grenada and in 1989 during Operation Just Cause in Panama. Reportedly, an airdrop operation was planned for September 1994 if the introduction of troops into Haiti was to be a forced-entry operation. However, those examples are all cases in which the C-130, a tactical airlift plane that is used routinely for shorter-range airdrop missions, could be employed. A brigade airdrop over strategic distances would be more demanding, which has led some analysts to suggest that it is an unlikely event. Reports suggest that defense planners were considering a brigade airdrop during Desert Shield/Desert Storm but ultimately decided otherwise.

Lesser Regional Contingencies. Smaller operations can include a wide variety of contingencies from humanitarian relief efforts to conflicts short of large-scale warfare. Operations in Somalia, Rwanda, Haiti, and Bosnia are some recent examples. Smaller-scale operations would most likely be conducted without the benefit of activating reserve aircrews or the Civil Reserve Air Fleet, and thus they could heavily tax the active component of strategic airlift forces.

It may be difficult to gain access to some future battlefields because of rough terrain or lack of roads, railroads, or major airfields. In those cases, the C-17 may hold an advantage over the C-5D and C-33 because of its ability to take off and land on 3,000-foot runways. By comparison, the C-5 typically requires a runway of nearly 5,000 feet, and the C-33 would require a major airfield about 10,000 feet long. Cargo deliveries to contingencies in Korea and Southwest Asia would probably not

be constrained severely because of airfields with short runways. If, however, lesser regional contingencies took place in countries with limited airfields, the C-17's short-field takeoff and landing capability could be important. (C-130s can also land on 3,000-foot runways, but they cannot carry outsize cargo.)

Critics have pointed out that since the C-17 distributes its weight load over fewer wheels than other military transports, such as the C-5, a C-17 landing can put significant stress on a runway's pavement.[9] That stress might be more severe if fuel was unavailable at an airfield, since the C-17 would be heavier because it would need to carry more fuel for its return flight. Nevertheless, in considering both runway length and weight-bearing capacity, the C-17 can land on approximately 3,700 airfields outside the United States compared with 2,300 for the C-5.

Direct Delivery. Under the concept of direct delivery, strategic airlifters would carry cargo intercontinental distances to airfields near the battle front, bypassing main operating bases. Today, C-130s are used to relocate critical supplies to forward airfields; most vehicles, however, can either be driven or flown to a battle front, and other equipment is moved by ground transportation.

Like other military transports such as the C-5, the C-17 has redundant systems and other specialized equipment to help it detect, avoid, and survive missiles and antiaircraft artillery. Military planes can also load and unload equipment quickly so that they can minimize their time in a hostile environment.

As part of the Tactical Utility Analysis, DoD's Director for Program Analysis and Evaluation is analyzing the importance of direct delivery within the context of a major regional contingency. Using strategic airlifters in that manner could reduce the amount of time needed to deliver specific units to a battle front. The analysis should provide some insight into whether those missions could significantly lessen the amount of time needed to deliver forces to a conflict.

Yet some analysts question whether or how frequently the C-17 would be used for direct delivery. Historically, the Army has preferred to deploy into main operating bases rather than forward airfields, allowing troops time to mass forces before initiating maneuvers.[10] Nor is direct delivery a major factor in DoD's planning for two major regional contingencies, although it may be more important for smaller operations. And some people question whether such a costly aircraft would be used in a hostile environment.

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9. Gebman, Batchelder, and Poehlmann, *Finding the Right Mix of Military and Civil Aircraft*, Chapter 5.

10. General Accounting Office, *C-17 Aircraft*, p. 14.

Intratheater Deliveries. Currently, the C-130 is the primary aircraft that the Air Force uses for tactical airlift operations. Although it performs that mission very capably, its cargo hold cannot fit outsize equipment. If the C-17 was used for intratheater missions, it would provide the capability to quickly reposition key pieces of equipment such as Patriot missiles or multiple rocket launch systems. The Tactical Utility Analysis will address what role the C-17 might play in moving units within Korea or Southwest Asia.

However, there may be reason to question whether the C-17 would be used for intratheater deliveries, particularly during major regional contingencies. When the Air Force first planned to purchase 210 planes during the Cold War, it intended for the C-17 to routinely move cargo within a theater, replacing C-130s that it planned to retire. A 1990 Major Aircraft Review of the C-17 reduced the size of that purchase to 120 planes. With a smaller fleet, using some C-17s as intratheater airlifters could increase the amount of time needed to deliver forces from the United States. Moreover, the Air Force does not now envision retiring many of its C-130s, so they can continue to fill the intratheater role.

Costs of Various Airlift Options

Details about contractors' specific proposals to build strategic airlift planes have been closely held. Press reports suggest, however, that competitive pressures among the three alternative aircraft have led to prices that are lower than expected. Costs are often stated in terms of flyaway cost—typically, the average unit price including the airframe and government-furnished equipment but excluding other items such as initial spare parts, support equipment, and government project management.

Future Costs of the C-17. In April 1995, the Air Force notified the Congress that it expects to pay an average flyaway price of $212 million each (in 1995 dollars) for an additional 80 C-17s. According to press accounts, McDonnell Douglas has since proposed selling its portion of those 80 planes (which excludes engines and some avionics equipment) at an average flyaway price of $190 million apiece.[11] By comparison, the first 40 C-17s had an estimated average recurring flyaway cost of about $300 million each (in 1995 dollars). (Throughout the rest of the memorandum, prices are shown in constant dollars—that is, adjusted for future inflation. However, current-dollar prices are the appropriate values to use for budgeting purposes.)

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11. Jeff Cole, "McDonnell Douglas Offers to Cut Price of C-17 Military Planes by Up to 40%," *Wall Street Journal*, July 31, 1995, p. A3; Tony Capaccio, "Boeing Proposal for C-17 Complement 'Viable,' Say AF Officials," *Defense Week*, September 25, 1995, p. 3.

The question at hand is how much the plane's producer can lower its costs. If DoD and the Congress agreed to purchase more than 40 C-17s, unit production costs would be expected to decline somewhat through learning. And average costs would also decline if the plane's annual rate of production was increased above its current level of eight per year. Some costs already appear to be dropping. For example, as a result of a review by the Air Force of what the C-17 should cost, McDonnell Douglas has begun transferring some of its manufacturing to its more efficient plants, reducing the number of assembly labor hours per plane, and lowering direct support costs. If those measures are pursued aggressively, lower costs may be possible.

CBO analyzed the feasibility of lowering costs for another 80 C-17s. Based on the cost histories of other large aircraft, CBO believes that an average flyaway cost of $203 million (in 1995 dollars) for 80 additional C-17s is consistent with learning efficiencies achieved in similar programs. Including the associated costs of support and initial spare parts would result in an average unit procurement cost of $251 million (in 1995 dollars).

The Air Force plans to award three contracts for every future C-17 production lot: one large contract for manufacturing the aircraft and two smaller ones covering field support (integrated logistics support, initial spare parts, and the like) and additional cost reduction initiatives or possible aircraft upgrades (called producibility enhancement/product improvement, or PE/PI). That three-contract approach was designed to increase the visibility of distinct elements of the program.

The C-17 program may face cost risks relating to the structure of production contracts for future lots. The Air Force is now negotiating with McDonnell Douglas on a firm, fixed-price contract with economic price adjustments for manufacturing airframes in the lot covering planes 33 to 40, along with fixed-price options for three subsequent lots and not-to-exceed contract options for any remaining production lots. Whether the Air Force can exercise those options will depend on annual appropriations by the Congress. Once the C-17 moved to a higher annual production rate, DoD would have to pay a price penalty if the Congress chose to purchase fewer aircraft in any future year, and prices for all subsequent lots would be open to renegotiation. That risk may be important at a time when the Congress is adding acquisition programs to the defense budget and, simultaneously, trying to eliminate the federal budget deficit.

Having three contracts governing each production lot could also pose some risk. The largest contract, which covers manufacturing, will be structured as a fixed-price contract in which the contractor bears the brunt if those costs are higher than expected. However, the structure and content of the field support and PE/PI contracts have not yet been established. DoD will need to be vigilant in monitoring

the C-17 program to make sure that manufacturing costs are not redistributed to the two smaller contracts.

Costs of Alternative Aircraft. The C-17's alternatives are subject to varying degrees of cost risk. Boeing has built more than 1,000 747 airframes in different configurations, which suggests that the cost risk associated with procuring C-33s is low. The Air Force would need to budget between $275 million and $300 million in development costs, however, in order to fit the 747-400 freighter with a wider side door and stronger floors. Two firm, fixed-price contracts with economic price adjustments would govern the manufacturing of C-33s—one covering the aircraft system and another for contractor logistics support.

Lockheed Martin's proposal for the C-5D model incorporates substantial changes from the existing C-5B that could improve the reliability of a plane that had significant maintenance problems during the Persian Gulf War.[12] Major upgrades include a new engine (the General Electric CF6-80C2, which is used on some 747s, 767s, Airbus 300s, and MD-11s), a new digital cockpit with the same avionics software that is being developed for the C-130J, and a number of other measures to improve the reliability and maintainability of the plane.

Lockheed demonstrated its ability to restart C-5 production when it produced the C-5B during the 1980s. Based on that experience, CBO estimates that the manufacturer could reopen the production line using much of the same production equipment at a start-up cost of $850 million. Those costs could be higher, however, if new tooling and production equipment is required. Since the D model includes significant upgrades that have not yet been demonstrated, there may be a greater degree of technical risk associated with that program than with the C-17 or C-33. For example, it is unclear whether the development schedule for the cockpit is achievable or whether it could result in program delays. A restart of the C-5 production line would most likely be governed by a fixed-price contract that covers start-up costs and airframe manufacturing and possibly another that covers contractor logistics support.

Acquisition Costs for Three Illustrative Options. The flyaway price can be a misleading measure for comparing the C-17 with alternative aircraft because it does not reflect all costs that the government would need to incur. Moreover, because the C-33 and C-5D can carry larger average payloads than the C-17, the Air Force might need fewer than 80 of them.

A better approach is to compare the full cost that the Air Force would need to pay in order to complete its strategic airlift acquisition program. That full cost

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12. John Lund, Ruth Berg, and Corinne Replogle, *An Assessment of Strategic Airlift Operational Efficiency*, R-4269/4-AF (Santa Monica, Calif.: RAND, 1993).

includes not only total flyaway costs but any additional development costs as well as initial spare parts, training, and other support equipment. Since the costs of operating and supporting an aircraft over its service life are sometimes larger than acquisition costs, they are extremely important as well.

To provide an idea of the range of alternatives, CBO estimated the costs of acquiring 80 additional C-17s, buying only C-5Ds, or purchasing a mixture of C-17s and C-33s. DoD is considering a much larger number of airlift alternatives than those provided here—these should be considered illustrative, not exhaustive.

CBO designed the options such that, when combined with the Air Force's expected strategic airlift fleet for 2006 (including no C-141s but 104 C-5A/Bs, 37 KC-10s devoted to airlift, and CRAF Stage 2), each option would be able to deliver the same amount of cargo to a single Southwest Asian contingency within the same two- to three-week period. CBO did not estimate cargo deliveries for a conflict on the Korean Peninsula or for two nearly simultaneous contingencies.

To make those estimates, CBO used the Airlift Cycle Assessment System (ACAS), a spreadsheet model developed by the Air Force for simple estimates of delivery capability. The ACAS model does not simulate the loading, departure, and landing of individual planes. Instead, it calculates how quickly a fleet can deliver a specific amount of bulk, outsize, and oversize cargo tonnage by distributing that weight among the airlift fleet based on the average payload of each type of aircraft. Since real-world airlift deliveries are also constrained by the shape and volume of individual pieces of equipment, the ACAS model probably understates the amount of time required to deliver cargo. Requirements were provided by the Department of Defense and match the shares of outsize, oversize, and bulk cargo planned for a deployment to Southwest Asia.

CBO's calculations assume that Southwest Asian and en route airfields have adequate ramp space, refueling supplies, material-handling equipment, and personnel to unload and service planes—in other words, that maximum on-the-ground (MOG) constraints are not very restrictive. If those resources were constrained, each option would take considerably longer than two to three weeks to deliver the cargo. Since the C-17 is smaller and more maneuverable on the ground than the C-33 or C-5D, those options with more C-17s might take less time to complete deliveries when airfield space was limited.

In its 1993 analysis, the Institute for Defense Analyses looked at how sensitive airlift deliveries are to airfield constraints by restricting the amount of space available at airfields to that experienced during the first 45 days of Operation Desert

Shield.[13] Under those conditions, it concluded, options with larger numbers of C-17s performed better. If space is equally constrained in the future, airfields may not be able to accommodate numerous large planes at the same time.

But would those same conditions exist in the future? Very few airfields were available to unload equipment during the early part of the Gulf War: nearly 60 percent of airlift missions were unloaded in Dhahran, and some airfields such as those in King Khalid Military City and at King Fahd International Airport were used only minimally or did not open until later in the operation.[14] Based on that experience, caution might argue in favor of assuming that conditions would be the same in the future. However, the United States has kept a military presence in the Persian Gulf since that war—an indication that countries such as Saudi Arabia may be more willing to open their facilities to U.S. forces.

All estimates of cargo deliveries are extremely sensitive to assumptions about MOG constraints. Frequently, airlift models assume that a single value adequately captures all aspects of MOG: often, it is characterized as the maximum number of aircraft that can be serviced simultaneously at an airfield. However, airlift deliveries depend not only on the amount of ramp space but also on the availability of fuel, equipment to unload cargo, ground transportation vehicles, and personnel to service the aircraft. For example, early airlift deliveries to Saudi Arabia were constrained not only by lack of access to airfields but also by too few trucks and drivers to move fuel from storage facilities to aircraft that needed refueling.[15] Once military officials realized the problem, they sent additional trucks and personnel to ease the situation. Some military officials believe that during the Gulf War, the availability of fuel constrained airlift operations more tightly than airfield ramp space.[16] If that is true, deliveries by smaller planes might not fare any better than those by larger ones.

By assuming that adequate ramp space is available, CBO's calculations may overstate the delivery capability of alternatives that include large planes such as the C-5D or C-33. However, other factors might constrain airlift operations more than ramp space, and thus it may not be appropriate to rule out options that include large planes. Moreover, improving the factors that limit airlift deliveries might be less expensive than purchasing enough planes to overcome those constraints.

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13. Greer, *Cost and Operational Effectiveness Analysis of the C-17 Program*, p. 62.

14. Lund, Berg, and Replogle, *An Assessment of Strategic Airlift Operational Efficiency*, pp. 41-45.

15. U.S. Air Force, *Gulf War Air Power Survey*, vol. 3, *Logistics and Support* (1993), p. 101.

16. Gebman, Batchelder, and Poehlmann, *Finding the Right Mix of Military and Civil Aircraft*, vol. 3, *Appendixes*, pp. 37-38.

Buying 80 additional C-17s, for a total of 120, would provide the Air Force with the most flexibility for addressing a wide range of military missions. CBO estimates that purchasing 80 more C-17s would cost $13 billion over the 1997-2001 period. (All costs are in 1996 dollars; see Table 1. Table A-1 in the appendix shows CBO's estimate of the costs of options in current dollars.) Total acquisition costs for all 80 planes would run to $20.7 billion. CBO estimates that the cost of manning and operating 80 additional C-17s through 2020 would be $15.5 billion, bringing total costs for buying and operating the planes to $36.2 billion over the next 24 years. This option would appeal to policymakers who believe that the United States is likely to become involved in conflicts in which DoD would need to use short runways or specialized missions such as strategic brigade airdrop, or who believe that airfields will be tightly constrained during future major regional contingencies.

Under Option 2, DoD would halt the C-17 program at 40 planes and reopen the C-5 production line to manufacture the D model. CBO estimates that procuring 65 C-5Ds would cost $9.7 billion over the 1997-2001 period and $11.7 billion over the entire procurement program (in 1996 dollars). Operating and supporting 65 C-5Ds until 2020 would cost $15.5 billion, bringing the total for procuring and operating those planes to $27.2 billion over the next 24 years. Option 2 would cost $9 billion less to purchase than Option 1 but just as much to operate and support.

Assuming that airfields had adequate space, a mixture of 40 C-17s and 65 C-5Ds would provide the same amount of delivery capability within the first two to three weeks of a major regional contingency as 80 additional C-17s. This procurement approach would also give the Air Force an airlift fleet with more planes that can carry outsize equipment compared with fleets that include C-33s.

If space at airfields is constrained, however, a fleet with greater numbers of large planes like the C-5 may not be able to deliver cargo as quickly. Nor can the C-5D handle some types of military operations that the C-17 can, such as delivering cargo in regions that have the shortest runways. With continued operational testing, the C-5 might eventually provide the Army with limited capability for airdrop, but the Air Force has decided that the plane will not be used to air-drop personnel. Nor is it likely that the Air Force would use the C-5 to deliver equipment to forward areas of military operations.

Option 3, procuring 32 additional C-17s plus 30 C-33s, would cost $13.3 billion over the 1997-2001 period and $15.5 billion through completion of the acquisition program (in 1996 dollars). CBO estimates that the cost of operating and supporting the additional C-17s and C-33s would total $12.9 billion through 2020, bringing total costs for the alternative to $28.3 billion over the 24-year period. Relative to Option 1, this alternative would cost more than $5 billion less to purchase and nearly $3 billion less to operate through 2020.

TABLE 1. ESTIMATED COSTS IN 1996 DOLLARS OF THREE STRATEGIC AIRLIFT OPTIONS (In millions)

	1997	1998	1999	2000	2001	Total, 1997-2001	Total, 1997-2020
Option 1: Buy 80 Additional C-17s							
Quantity Purchased	8	8	8	10	12	46	80
Acquisition Costs	2,510	2,490	2,430	2,670	2,910	13,010	20,730
Operation and Support Costs	0	0	50	140	250	440	15,470
Total Costs	2,510	2,490	2,480	2,810	3,160	13,450	36,200
Option 2: Buy 65 C-5Ds							
Quantity Purchased	4	10	12	12	12	50	65
Acquisition Costs	2,420[a]	2,010	1,840	1,780	1,630	9,680	11,690
Operation and Support Costs	0	0	0	120	290	410	15,540
Total Costs	2,420	2,010	1,840	1,900	1,920	10,090	27,230
Option 3: Buy 32 Additional C-17s and 30 C-33s							
Quantity of C-17s Purchased	8	8	8	8	0	32	32
Quantity of C-33s Purchased	1	1	6	6	6	20	30
Acquisition Costs	2,930[b]	2,660	3,400	3,120[c]	1,170	13,280	15,470
Operation and Support Costs	0	0	50	140	290	480	12,850
Total Costs	2,930	2,660	3,450	3,260	1,460	13,760	28,320

SOURCE: Congressional Budget Office.

NOTE: All options exclude any costs associated with procuring or operating the first 40 C-17s.

a. Includes $850 million for the cost of restarting the C-5 production line.

b. Includes $275 million in costs to develop the C-33.

c. Cost declines in 2000 because advanced procurement funds are no longer needed for the C-17.

The third option would also provide the same amount of delivery capability as 80 additional C-17s when airfields were not constrained. Given the current emphasis on prepositioning outsize materials for major regional contingencies, outsize cargo makes up a smaller share of airlift requirements than before. Under those conditions, a fleet with fewer planes that are capable of carrying outsize cargo may still provide sufficient delivery capability.

Such a fleet could not, however, handle unique military missions as well as 80 more C-17s. And if little ramp space was available in future major regional conflicts, a fleet with C-33s probably would not be able to deliver cargo as quickly as 80 more C-17s. (The C-17 is better able to maneuver on the ground, and the large size of the C-33 and the long runway it requires could limit airlift deliveries.)

However, a mix of 32 more C-17s and 30 C-33s might still provide sufficient capability. For example, if the Air Force decided to use its existing C-5s to air-drop heavy equipment, it could conduct some airdrop missions using a combination of C-5s and C-17s. Policymakers might choose this option if they believe the United States will probably not need to conduct military missions such as air-dropping an entire brigade of troops or delivering cargo directly to forward airfields.

Following Air Force planning, CBO's estimates assume that the C-17 will operate many more hours per year than either the C-5D or the C-33. The Air Force plans to fly the C-33 just 650 hours per year, compared with 1,430 hours per year for the C-17 (see Table 2). Thus, the C-33's costs for operation and support (O&S) are considerably lower—$10 million per plane rather than $13 million for the C-17 (in 1996 dollars). The C-5D would fly 440 fewer hours each year than the C-17, but its O&S costs per plane would be higher.

CBO estimates that, on a per-hour basis, O&S costs for the C-17 are lower than for either alternative, averaging $9,100 per flight hour compared with $15,900 per flight hour for the C-33 and $14,900 for the C-5D. The Air Force could lower the C-17's total O&S costs by changing the mix of active-duty and reserve pilots who fly the plane or simply reducing its annual flying time.

TABLE 2. ESTIMATED ANNUAL OPERATION AND SUPPORT COSTS FOR SELECTED AIRLIFT AIRCRAFT

Type of Aircraft	Number and Type of Crew per Aircraft	Number of Aircraft per Squadron	Flying Hours per Aircraft	Cost per Aircraft (Millions of 1996 dollars)	Cost per Flying Hour (Thousands of 1996 dollars)
C-17	3.0 Active and 2.0 Reserve Crews	12	1,430	13.0	9.1
C-5D	1.8 Active and 1.8 Reserve Crews	16	990	14.7	14.9
C-33	1.5 Active and 3.5 Reserve Crews	13	650	10.3	15.9

SOURCE: Congressional Budget Office compilation of estimates from the Air Force's Systematic Approach to Better Long-Range Estimating (SABLE) model, version 95-1, December 1994, and estimates by contractors.

NOTE: Operation and support (O&S) cost estimates are based on many factors, such as the number of crews per aircraft, the type of crew per aircraft (active, reserve, or both), the number of aircraft per squadron, and the number of flying hours per aircraft. Based on the available data, CBO is unable to calculate an O&S cost per aircraft that considers all of those factors uniformly for all aircraft. These estimates do not necessarily equal budgeted amounts because they are based on mathematical models that approximate long-run costs.

APPENDIX: SUPPLEMENTAL TABLE

TABLE A-1. ESTIMATED COSTS IN CURRENT DOLLARS OF THREE STRATEGIC AIRLIFT OPTIONS (In millions)

	1997	1998	1999	2000	2001	Total, 1997-2001	Total, 1997-2020
Option 1: Buy 80 Additional C-17s							
Quantity Purchased	8	8	8	10	12	46	80
Acquisition Costs	2,760	2,820	2,840	3,210	3,600	15,230	25,350
Operation and Support Costs	0	0	50	160	290	500	25,410
Total Costs	2,760	2,820	2,890	3,370	3,890	15,730	50,760
Option 2: Buy 65 C-5Ds							
Quantity Purchased	4	10	12	12	12	50	65
Acquisition Costs	2,660[a]	2,280	2,140	2,140	2,020	11,240	13,840
Operation and Support Costs	0	0	0	140	350	490	25,270
Total Costs	2,660	2,280	2,140	2,280	2,370	11,730	39,110
Option 3: Buy 32 Additional C-17s and 30 C-33s							
Quantity of C-17s Purchased	8	8	8	8	0	32	32
Quantity of C-33s Purchased	1	1	6	6	6	20	30
Acquisition Costs	3,220[b]	3,020	3,970	3,750[c]	1,450	15,410	18,260
Operation and Support Costs	0	0	50	160	350	560	20,800
Total Costs	3,220	3,020	4,020	3,910	1,800	15,970	39,060

SOURCE: Congressional Budget Office.

NOTE: All options exclude any costs associated with procuring or operating the first 40 C-17s.

a. Includes $850 million for the cost of restarting the C-5 production line.

b. Includes $275 million in costs to develop the C-33.

c. Cost declines in 2000 because advanced procurement funds are no longer needed for the C-17.